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D5.1 Scenario description and validation procedure for the validation trials

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Dissemination level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

1. Executive Summary

This document constitutes the Deliverable D5.1 of the CADDY project. It defines the validation scenarios, objectives, procedures and criteria for CADDY subsystems and system validation. Deliverable elaborates key performance indicators, method used for validation tasks assessment and defines assessment body. The main objective of validation assessment is to demonstrate that the system is suitable for its targeted/intended purpose.

Deliverable is presented in a form of a Validation Plan, developed for final evaluation of the system performance. Validation plan defines validation methods and activities. These activities provide evidence to document system compliance with the validation requirements. The Validation Plan activities are categorized in four categories: validation of the hardware safety, validation of the system functionalities (first validation trial), validation of the overall system in real life scenarios (second validation trial) and validation of the human machine interface and ergonomics.

Validation plan for each of the categories defines:

- objectives - aim of validation
- procedures - how to perform the validation
- validation criteria - objective or subjective validation targets/measures to be assessed against the validation results
- validation body - who performs the validation

This validation plan is not to be considered as a final document. Validation procedures and criteria could be modified according facts not know at the moment, to incorporate e.g. recent and upcoming research results, new vehicle design and/or new knowledge. Nevertheless, validation objectives should be maintained.

2. Introduction

Validation activities such as testing and validation test assessment, planned at the later stage of the project, shall be carried out according to the Validation Plan developed in this report. The result from validation activities will be a basis for final evaluation of the system performance.

The multilayer validation should prove that safety of the diver is preserved, ensure that all aspects of the project are properly addressed, at the same time estimating the level of maturity of the solution and giving the guidelines for the future work. From research point of view, validation tasks are tailored to indirectly evaluate whether research topics/objectives are met: "Seeing the Diver", "Understanding the Diver", and "Diver-Robot Cooperation and Control". From functionality point of view, validation assessment provide evidence that developed system is able to play the simultaneous roles of: dive buddy *"observer",* dive buddy *"slave",* and dive buddy *"guide".*

The safety validation ensures diver safety when interacting with autonomous underwater vehicle, meaning that developed system agents for diver assistance are safe to be used.

Validation trials will be performed on two occasions during the project within T5.2 and T5.3 of the work plan. First validation trial is scheduled for the end of the second year of the project when not all components and functionalities of the system will be developed. During the first validation period, specific sub-functionalities and sub-tasks will be assessed, validating the state of the project progress, trends and accomplishments. Assessment body will identify strengths and provide guidelines how to address weaknesses.

Final system validation is based on complex trials representing Real-Life Scenarios. For successful accomplishments of these scenarios combination of the system functionalities is required. According to project DoW [1], the Real-Life validation scenarios are: Search and rescue (S&R) mission and Underwater archaeology mission. Assessment of the second trial will represent final achievement of the system developed during this project.

Throughout the validation trials, the ergonomics and the comfort of the diver supporting system and human-machine interface will be evaluated. This validation task is related to subjective assessment of diver confidence, comfort and safety in using CADDY system and it will be performed by the divers, end users of the system.

3. Validation Plan

A Validation Plan shall be developed to provide the evidence needed for final evaluation of the system performance. The selected validation methods shall be specified as activities in the Validation Plan. A validation method shall be described in sufficient detail to carry out the activities and obtain reliable evidence. These activities provide evidence to document compliance with the validation requirements.

The Validation Plan consists of activities which are categorized in four categories: validation of the hardware safety, validation of the system functionalities (first validation trial), validation of the overall system in real life scenarios (second validation trial) and validation of the human machine interface and ergonomics. The description of each activity is given in the following sections.

3.1. Safety Validation

The primary aim of safety validation is to ensure diver safety when interacting with autonomous underwater vehicle. This part of validation plan is compiled in accordance with CADDY deliverable D6.1.1 [2], which defines safety requirements for diver assistant system. Successful validation of the hardware safety means that developed autonomous underwater vehicle for diver assistance is safe to be used. Validation is performed by the research partners, developers of the vehicles.

Objective

The objective is to assess if safety rules from D6.1.1 for development of the CADDY diver assistance vehicle RECUV, are met.

Procedure and Validation Criteria

Follow the validation procedure step by step and fill out the Safety validation form (ANNEX A.). Consult the D1.3 [4] for a hardware details related to the overall robotic assistance system.

Validation criteria: all safety aspect from the validation plan needs to be properly addresses and all answers in the Safety validation questioner are positive.

Table: safe voltage that diver may come to contact with according to [3]

Supply	Safe Body Current [mA]		Body Route Resistance [Ω]		Safe Voltage	
					Maximum [V]	Nominal [V]
	(I)	x	(R)	=	(V)	(V)
DC without a suitable trip device	40		750		30	24
AC without a suitable trip device	10		750		7.5	6
DC with a suitable trip device	570		500		285	250
AC with a suitable trip device	500		500		250	250

Note: A suitable trip device is one with a reaction time of 20ms or less.

TASK	DESCRIPTION	PROCEDURE	CRITERIA
I. MECHANICAL REQUIREMENTS			
I.a) check propellers	The propellers of the AUV's should be guarded.		• propellers cannot harm the diver
II. ACOUSTIC REQUIREMENTS *Analyze if specifications of the acoustic devices installed on the vehicle (modem, Sonar, Doppler velocity log) met the safety requirements from the D6.1.1.*			
II.a) check modem		See the specifications in datasheet	• safety requirements from the D6.1.1. chapter 2 and chapter 4 are met
II.b) check sonar			
II.c) check DVL			
III. LOW FREQUENCY ACOUSTIC REQUIREMENTS *Although it is not envisioned that any low frequency acoustic source will be used on the RECUV, make sure that sounds close to the human lung resonant frequency of 42 Hz, even at low power should not be emitted, simply to avoid the discomfort of the diver.*			
III.a) check all acoustic devices			• sound source with the frequency close to the human lung resonant frequency of 42 Hz is not used
IV. POWER REQUIREMENTS *Table 1. shows safe voltage that diver may come to contact with according to [3].*			
IV.a) check power requirements		See the specifications in datasheet	• BUDDY is supplied with the "safe voltage" (see Table above) and complies with the IMCA code of practice, [3]
V. KILL SWITCH *Assess the functionality of the Kill Switch (emergency stop) as a mean of stopping during an emergency. This validation covers direct contact kill switches (mechanical or magnetic) as well as remote kill switches such as EM (radio light) or acoustic emergency stopping devices, if any exists. It is possible to have a automatic kill switch activation when safe distance between AUV and the diver is violated but this is not the scope of this phase of validation.*			
V.a) check functionality			• kill switch stops the operation of the

			vehicles immediately
V.b) check access		Inspect the position of the kill switches and number of kill switches.	• safe stopping of the vehicle from all sides is ensured
V.c) check tagging		inspect if kill switches are tagged carefully and if their function is obvious.	• quick, simple and obvious operation is allowed to anyone even for panicking user
...			

3.2. First validation trial: validation of functionalities

The quality and efficiency of the CADDY system will be tested and assessed during two validation periods and assessment will be based on validation criteria (key performance indices). First validation trial is scheduled for the end of the second year of the project when not all components and functionalities of the system will be developed. During the first validation period, specific sub-functionalities and sub-tasks will be assessed, validating the state of the project progress, trends and accomplishments, rectifying the significant issues and providing the guideline for the future work. Validation will be performed by the Advisory Board members and DAN Europe together with research partners of the CADDY project in charge for particular robot or application.

Objective

Objective of the first validation period is to assess system capability to perform some of the dive buddy "guide", dive buddy "slave" and dive buddy "observer" functionalities and to comply with all safety aspects of the real mission. Successful validation at this stage means that research objectives are addressed properly and developed subsystems and applications/algorithms of the CADDY system, are fully functional. It is important precondition for success of the system performance when assessed in real life situations.

Procedure and Validation Criteria

Please follow the table below to perform the validation. Table gives validation description, procedure and criteria. Fill out the validation form (ANNEX B.) with the trial results.

TASK	DESCRIPTION	PROCEDURE	CRITERIA
I. TESTING "GUIDE" FUNCTIONALITY			
I.a) vertical guidance down	buddy should be able to safely take the diver to a desired depth and lead him/her to the surface	specify desired depth; buddy keeps track of the diver; diver follows the buddy to a specified depth	• buddy keeps an eye on the diver constantly • final depth matches desired depth
I.b) vertical guidance up		buddy keeps track of the diver; diver follows the buddy to a specified depth	• diver and buddy surface together • task accomplished without violating diving safety rules
I.c) steering the diver, control of the diver orientation	buddy should perform automatic manoeuvre in order to steer the diver to take and maintain desired orientation		• buddy steers the diver to the desired direction • diver is oriented correctly
I.d) buddy maintains the "communication" and "observation" position	Buddy automatically positions itself in the middle of the divers field of view, defined distance away from the diver, to ensure optimal conditions for diver-buddy communication or monitoring		• buddy understands and follows the diver's orientation • buddy maintains desired position for this task
II. DIVER BUDDY NONVERBAL COMMUNICATION			
II.a) vocabulary for non-verbal communication	Check availability of the initial vocabulary of signs, gestures and syntax and check if it covers all the foreseen situation for topic "Understanding the Diver" [6].		• vocabulary exist • it covers all foreseen situations
II.b) diver-buddy communication	Validate diver-buddy communication using standardized static and dynamic hand gestures from the diver symbolic vocabulary as well as using symbols (or sequences of symbols) that are defined for the purpose of compliant robotic task	Test communication using all categories: standard diving set of signs and gestures, custom set of signs and other means of communication. At this stage only subset of symbols and gestures will be validated. Validation subset and communication success rate are to	• successful diver-buddy comm. using standard diving vocabulary • successful diver-buddy comm. using custom vocabulary • successful diver-buddy comm. using other means of communication

	execution.	be defined prior to first validation trial.	
III. VALIDATION OF THE COMMUNICATION LINK BETWEEN THE SURFACE CONTROL CENTRE AND THE UNDERWATER AGENTS			
III.a) direct link diver - surface	Test all available communication channels and quality of the communication interface	Initiate and test communication from both sides	• communication link is functional and provides reasonable flow of information.
III.b) diver - surface via buddy			
III.c) buddy - surface			
III.d) communication interface		Test and evaluate the interface	• Interface is easy and intuitive to use. Provide recommendations for potential improvements
IV. POSE ESTIMATION BY LOCAL AND REMOTE SENSING			
IV.a) an online repository of diver pose datasets	Check availability of the online repository of diver pose datasets, obtained from remote (video, sonar) and local (DiverNet) sensing and check if it is relevant for the diver pose, behaviour, signs and gesture interpretation [5].		• an online repository of diver pose datasets exists • it is relevant for the purpose
IV.b) Pose estimation by local sensing	Validate methods for pose estimation but not interpretation at this stage.	Assess performance of the local sensing method (DiverNet), for the diver pose estimation. Assess ergonomics and comfort of the DiverNet in real missions/operation.	• reliable diver pose estimation • comfortable for divers to wear it
IV.c) Pose estimation remote sensing		Assess performance of a remote sensing for the diver pose estimation using: camera, stereo camera, high resolution sonar. Evaluate potential of different remote sensing techniques and provide recommendations for future work	• reliable diver pose estimation using camera • reliable diver pose estimation using stereo camera • reliable diver pose estimation using sonar
IV.d) Buddy interference in normal operation	The robotic buddy must manoeuvre safely around the diver in order to assume the best viewpoint for observation; at the same time, its		• Buddy should not at all, or only insignificantly interfere with the normal

	presence should not interfere with the normal unfolding of the mission. It is assumed that this trial will answer the question what are the optimal/preferred RECUV distance and angle for different observation sensors.		unfolding of the mission
V. SLAVE			
V.a) take a photo	hovering over a spot indicated by the diver's laser beam pointer and taking photos of the location	point a laser beam to the specific point	• buddy goes to the pointed position • buddy takes a photo
V.b) take a video for the mosaic	buddy acquires a series of overlapping photos for a mosaic upon request from the diver	Diver orders the buddy to acquire a photos for a mosaic or simply guides the diver	• buddy covers the area following the diver's order or following the diver • buddy takes a video
V.c) illuminate a site	buddy illuminates a site from different angles upon request from the diver		• buddy understands the request • buddy illuminates a site from different angles
V.d) carrying a tool or equipment	buddy carries a payload with tools and equipment upon diver request		• buddy understands the request • buddy carries a payload
...			

3.3. Second validation trial: Real-Life Scenarios

The activities of this task are related to the performance assessment and experimental validation of the integrated CADDY system. Assessment will be performed on the basis of the validation criteria in a form of the key performance indicators. The validation, objective assessment of validation criteria, judgement on the performance quality and safety validation will be performed by Advisory Board members and DAN Europe. It is important that divers, the main actors in the validation task execution, provide valuable input for the evaluators of the validation tasks.

Two validation Real-life tasks stated in the Description of Work of the CADDY project are the Search and Recovery mission and the Underwater Archaeology mission. Aim of the second validation trials is to prove that CADDY system is capable of performing and successfully completing real-time validation tasks in a safe and efficient manner.

3.4. Validation task: Search & recovery mission (S&R)

Objective

The objective of this task is to evaluate that CADDY system is capable of providing valuable help for divers during the search and recovery missions.

During the validation scenario, the diver tests the cognitive abilities of the CADDY system, the diver "observer" functionality. Diver communicates with the surface control centre, sharing the info or asking for advice.

Typical objective of the search mission is to scan the predetermined area, ensuring the fully coverage in a time and effort efficient way. Specific CADDY system objectives of the recovery validation mission are:

- to guide the diver efficiently in order to find/detect the object/objects located on the unknown position in the search area
- to provide communication link with the surface control centre in order help diver to identify detected object/objects
- to guide the diver to the safe location during the recovery of the object/objects. Recovery applicable only if it is possible and safe
- all tasks must be performed in a safe way

Procedure

Follow the validation procedure step by step and fill out the validation form (ANNEX C.).

a. Define a specific area at the trial venue to be covered in a predetermined path in order to simulate a real scenario of an S&R mission.

b. Define predetermined path of the search area in a typical lawnmower pattern. Set transect spacing/density according to environmental conditions e.g. visibility, currents.

c. Before an underwater mission starts, all participants in the trial are "informed" about the mission plan and procedures: the diver and diving supervisor, the CADDY system and CADDY supervisor.

d. Perform the Pre Dive Check. The diving supervisor and CADDY supervisor must perform the required checks before each dive according to the safety recommendations given in deliverable D6.1. Post dive checks are post dive debrief meetings are also recommended.

e. RECUV safety devices, mainly the kill switch, should be tested prior the dive.

f. Deployment of all CADDY system agents: autonomous vehicles (MOCOS and RECUV) and the diver tablet (DT) according to established procedures.

Criteria

Criteria is in project DOW referred to as a key performance indicators. Additional indicators may be defined by the Advisory Board members and DAN Europe or suggested by any of the project partners or end users (divers).

a. The main goal of the search and recovery mission and consequently the main validation criteria of the CADDY system is to support and aid diver to efficiently and successfully find all targets/objects in a defined search area, to recover the objects and safely recover the diver, upon mission completion.

b. The next important validation criteria is the safety of the diver. Diver safety area must be preserved throughout the mission. Safety recommendations elaborated in the deliverable D6.1 has to be followed at all time.

TASK	DESCRIPTION	PROCEDURE	CRITERIA
I. BUDDY "GUIDE" FUNCTIONALITY			
I.a) path following	Path following of the RECUV affects quality of the diver path following, and it affects the search mission performance indirectly.	Define a lawnmower pattern and initiate autonomous path following.	• The RECUV path following performance index is a valuable input for research partners of how to improve developed vehicles.
I.b) guiding the diver	The RECUV simply guides the diver underwater in order to follow the search path and makes sure that the diver is following the buddy, demonstrating the buddy "guide" functionality. The quality and precision of path following (for both the diver and RECUV) during mission should ensure that none of the targets/objects is missed out or any part of the search area remain uncovered.	Objective evaluation of the path following quality is achieved by assessing the path tracking error (distance between RECUV/diver actual position and desired position on the path). Objective measure based on tracking error should follow one of the frequently used measures such as maximum tracking error, average or average square tracking error etc.	• During the search mission, diver is the one doing the search, therefore, for the search mission performance, divers path following quality is more important than the RECUV path following quality. For that reason we recommend using the diver path following performance index for validation of the search and recovery trial. • Path following performance is often measured as a combination of the path tracking quality and the effort needed to complete the mission. Even though effort may not be the primary scope of the validation task, this plan suggests including it as an added value of the system. Note: Processing of data provided by the DiverNet could yield diver effort estimate.
I.c) object recovery	The task is to recover a specific object(s). Upon finding the object, depending on size and type of the object, diver decides to: • recover the object and continue the search (small and safe object) • recover the object, abort the search, and start diver recovery to the safe location • mark the location of the object and continue the search (big		• efficiently and successfully find all targets/objects in a defined search area, to recover the objects and safely recover the diver, upon mission completion.

	and/or suspicious object)		
II. BUDDY "OBSERVER" FUNCTIONALITY			
II.a) behaviour interpretation	Divers behaviour interpretation by simulating the pose from the diving situations behaviour repertoire.	Assess speed and success of the divers behaviour interpretation, focusing on distinguishing normal diving behaviour from a divers' behaviour in stressful/anxiety situations.	• The rate of correctly interpreted behaviours and speed of interpretation. The performance is assessed by the validation evaluators and divers participating in the validation trail and the results should exceed the limits set by the validator.
II.b) gesture interpretation	Symbolic gesture interpretation by communicating with the RECUV.	Assess speed and success of the symbolic signs and gestures interpretation and confirmation.	• The rate of correctly interpreted and confirmed signs and gestures and speed of interpretation. The performance is assessed by the validation evaluators and divers participating in the validation trail and the results should exceed the limits set by the validator.
II.c) changing mission parameters	Assessment of RECUV ability to react appropriately on change of the mission parameters.	At any time the diver can stop the mission, change the mission parameters. The diver informs RECUV about the mission change, e.g. from "search and area" mission to "go to surface mission".	• Validation criteria is speed and success of RECUV reaction to a change in the mission plan.
II.d) commanding the RECUV	Assessment of RECUV ability to perform compliant tasks.	Diver commands the RECUV to perform a compliant task.	• Subjective assessment of the quality RECUV compliant tasks performance.
III. COMMUNICATION WITH THE SURFACE			
III.a)	Diver communicates with the surface control centre, sharing the info or asking for advice.		• Communication link with the surface control centre is available when needed, provides reasonable flow of information to unsure success of the mission • communication interface is easy and intuitive to use.
…			

3.5. Validation task: Underwater archaeology mission

Objective

The objective of this task is to evaluate that CADDY system is capable of providing valuable help for divers during the excavation and documentation of an underwater site. Specific CADDY system objectives of the underwater archaeology validation mission are:

- to guide the diver directly and accurately to the known, previously defined position in the site area
- to perform diver slave tasks such as to take a photo of an object or an area, to make a photo mosaic of a selected area or to illuminate a specific part at the sea bottom
- to continuously monitor, observe the diver at all times during the dive by assessing the divers behaviour and interpreting symbolic signs and gestures communicated by the diver
- to guide the diver to the safe location upon mission completion
- all tasks must be performed in a safe way

Procedure

Follow the validation procedure step by step and fill out the validation form (ANNEX D.).

a. Define a specific boundaries of the trial area to simulate a real life scenario of an underwater archaeology mission.

b. Define fixed position in the trial area where the diver should be guided to. It can be position where the previous diver has stopped with the documentation of the underwater site or previously determined location by some e.g. remote sensing method (sidescan sonar image) which needs to be inspected.

c. Before an underwater mission starts, all participants in the trial are "informed" about the mission plan and procedures: the diver and diving supervisor, the CADDY system and CADDY supervisor.

d. Perform the Pre Dive Check. The diving supervisor and CADDY supervisor must perform the required checks before each dive according to the safety recommendations given in deliverable D6.1. Post dive checks are post dive debrief meetings are also recommended.

e. RECUV safety devices, mainly the kill switch, should be tested prior the dive.

f. Deployment of all CADDY system agents: autonomous vehicles (MOCOS and RECUV) and the diver tablet (DT) according to established procedures.

Criteria

Criteria is in project DoW referred to as a key performance indicators. Additional indicators may be defined by the Advisory Board members and DAN Europe or suggested by any of the project partners or end users (divers).

- The main goal of the underwater archaeology mission and consequently the main validation criteria of the CADDY system is to support and aid diver to efficiently and successfully complete all required tasks and demonstrate all system functionalities described in Project DoW:
  - to guide the diver to the predefined position
  - to perform commanded slave tasks
  - to monitor if divers behaviours deviate from the normal
  - to safely recover the diver, upon mission completion.
- The next important validation criteria is to ensure safety of the diver. Diver safety area must be preserved throughout the mission. Safety recommendations elaborated in the deliverable D6.1 has to be followed at all time.

TASK	DESCRIPTION	PROCEDURE	CRITERIA
I. BUDDY "GUIDE" FUNCTIONALITY			
I.a) guiding the diver	Demonstration of the buddy "guide" functionality. The RECUV guides the diver directly to the defined underwater location making sure that the diver is following the buddy. It is not only important that diver is brought to the predefined location but also how accurate is an underwater position/location the diver is guided to.		• Validation criteria, exact acceptance accuracy will be established during the field trials.
II. BUDDY "SLAVE" FUNCTIONALITY			
II.a) take a photo of a part of the sea bottom	While on the site, the diver communicates with the RECUV using symbolic hand gestures, changes the mission parameters or commands the RECUV to perform some compliant slave tasks.		Each of the performed slave tasks should comply with the validation criteria: • speed and success of RECUV reaction and the mission performance • precision and compliance of RECUV operations during the task
II.b) make a mosaic of a selected area			
II.c) illuminate a specific area of the sea bed			
III. BUDDY "OBSERVER" FUNCTIONALITY			
III.b) behaviour interpretation	The RECUV monitors diver behaviour at all time. Diver should simulate behaviour which is during the project identified as a deviation from a normal condition	Assess speed and success of the divers behaviour interpretation, focusing on distinguishing normal diving behaviour from a divers' behaviour in stressful/anxiety situations.	• The rate of correctly interpreted behaviours and speed of interpretation. The performance is assessed by the validation evaluators and divers participating in the validation trail and the results should exceed the limits set by the validator.
III.c) gesture interpretation	Symbolic gesture interpretation by communicating with the	Assess speed and success of the symbolic signs and gestures	• The rate of correctly interpreted and confirmed signs and gestures and speed of interpretation.

	RECUV.	interpretation and confirmation.	The performance is assessed by the validation evaluators and divers participating in the validation trail and the results should exceed the limits set by the validator.
IV. COMMUNICATION WITH THE SURFACE			
IV.a)	Diver communicates with the surface control centre, sharing the info or asking for advice.		• Communication link with the surface control centre is available when needed, provides reasonable flow of information to unsure success of the mission • communication interface is easy and intuitive to use.
…			

3.6. Validation of the Human Machine Interface, Ergonomics

The diver supporting system should be equipped with interface to offer the diver a ergonomic and comfortable environment and joy-able diving experience. The quality of human-machine collaboration depends on: human users thrust, confidence in the support system, ergonomics and performance in complex tasks. This validation task is related to subjective assessment of diver confidence, comfort and safety in using CADDY system and the ergonomics of the system. Assessment will be performed by the divers, end users of the system, using the questionnaire developed for validation purpose and based on the evaluation of the user interfaces [7] and task work load [8].

Objective

The objective of this task is to evaluate whether the divers, end users of the CADDY system, consider the system safe, reliable, comfortable and easy-to-use. The system should not increase mental workload of the diver for the particular task.

Procedure

After every mission, diver/divers involved in the mission need to fill out the validation form (ANNEX E.).

Criteria

Validation Criteria is not straightforward as it is in the case of the previous validations categories. It is purely subjective impression whether the developed system and interface offer the diver a ergonomic and comfortable environment and reduce divers workload and stress. Subjective assessments could differ significantly among divers. Validators, project partners and end users, should draw final conclusion from the filled validation forms.

References

1. "Description of Work", Project acronym: CADDY, Project full title: " Cognitive autonomous diving buddy ", Grant agreement no: 611373

2. Deliverable D 6.1.1. "Safety rules for the development of diver assistance system components"

3. Code of Practice for The Safe Use of Electricity Under Water. IMCA document D 045, R 015, October 2010.

4. Deliverable D1.3 - Report on integration of the overall robotic assistance system – experiments and performance

5. Deliverable D2.4 - An online repository of diver datasets obtained from remote (video, sonar) and local (DiverNet) sensing

6. Deliverable D3.1 - Initial list of gestures and syntax

7. IsoMetrics - Questionnaire for the evaluation of the graphical user interfaces based on ISO 9241/10

8. Hart, S. G. (2006). NASA-Task Load Index (NASA-TLX); 20 years later. In Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting (pp. 904-908). Santa Monica, CA: Human Factors & Ergonomics Society.

ANNEX A. CADDY Safety Validation Questionnaire

The purpose of this questionnaire is to assess the safety of CADDY autonomous vehicles. Please indicate the vehicle compliance with each of the statements, by placing an **x** in the appropriate box. Fill out the comment tab where necessary.

Index	Safety		yes	no	comment
1	Are the propellers of the AUV guarded in order to prevent injuries?				
2	Do acoustic devices installed on the vehicle (modem, Sonar, Doppler velocity log) meet the safety requirements from the D6.1.1.	Modem			
		Sonar			
		DVL			
		other			
3	Sound source with the frequency close to the human lung resonant frequency of 42 Hz is not used.				
4	RECUV power supply is in compliance with IMCA code of practice.				
5	Activation of the kill switch stop the operation of the vehicle immediately.	Sw.1 Sw.2			
		Sw.3			
		Remote1			
		Remote2			
6	Position and number of kill switches ensure safe stopping of the vehicle from all sides.				
7	It is quick, simple and obvious to operation kill switches even for panicking user.				

ANNEX B. CADDY First Validation Trial Questionnaire

The purpose of this questionnaire is to assess compliance of CADDY system with the validation plan. Please indicate the system compliance with each of the statements, by placing an **x** in the appropriate box. Fill out the comment tab when necessary.

Index			yes	no	comment
1 2	Is online repository of diver datasets obtained from remote and local sensing, available and relevant? Is Initial list, vocabulary of signs, gestures and syntax, available and covers all the foreseen real-life situation?				
3	Is RECUV able to lead the diver to dive together as well as to surface together? Validation criteria: successful vertical guidance without violating diving safety rules.	to dive together to surface together			
4	Is RECUV able to automatically manoeuvre in order to steer the diver to take and maintain desired orientation. Validation criteria: diver is oriented correctly.				
5	Is RECUV able to automatically position itself in the middle of the divers field of view, defined distance away from the diver, to ensure optimal conditions for diver-buddy communication or monitoring. Validation criteria: RECUV maintains desired position for this task.				
6	Is diver-buddy communication, limited to the defined vocabulary, sufficiently good for successful performance of all system functionalities	Standard diving set of signs and gestures			
		Custom set of signs and gestures			
		Other means of communication			

7	Is communication link between the surface control centre and the underwater agents available when needed and provides reasonable flow of information using all possible topologies?				
8	Could DiverNet be successfully used for diver pose estimation?	reliable diver pose estimation			
		comfortable for divers to wear it			
9	Is the robotic buddy capable of manoeuvring safely around the diver in order to assume the best viewpoint for observation, without interfering with the regular mission operations?				
10	Does system perform successfully dive buddy *"slave"* tasks?	Take a photo Illuminate the area Collect data for video mosaic			
		Carrying a payload with tools and equipment			

ANNEX C. CADDY Second Validation Trial Questionnaire: Search & recovery mission (S&R)

The purpose of this questionnaire is to assess compliance of CADDY system with the validation plan. Please indicate the system compliance with each of the statements, by placing an **x** in the appropriate box. Fill out the comment tab when necessary.

Index		yes	no	comment
1	Is diver supported by the CADDY system able to efficiently and successfully find all targets/objects in a defined search area, to recover the objects and safely recover the diver, upon mission completion?			
2	Is CADDY system able to support diver to recover or at least geo-reference the objects and safely recover the diver, upon mission completion?			
3	Is diver safety area preserved throughout the mission according to safety recommendations elaborated in the deliverable D6.1?			
4	Define path following quality objective measure (diver path following performance index) and the validation target. Assess divers path following quality against established measure.			
5	Define path following quality objective measure (RECUV path following performance index) and the validation target. Assess RECUV path following quality against established measure.			
6	Is communication link between the surface control centre and the underwater agents available when needed and provides reasonable flow of information using all possible topologies?			
7	Assess the speed and success of the divers behaviour interpretation, focusing on distinguishing normal diving behaviour from a divers' behaviour in stressful/anxiety situations. Define the validation target and assess the			

	rate of correctly interpreted behaviours and speed of interpretation against the target.			
8	Assess the speed and success of the symbolic signs and gestures interpretation and confirmation. Define the validation target and assess the rate of correctly interpreted and confirmed signs and gestures as well as speed of interpretation against the target.			
9	Assess the ability of RECUV to react appropriately on change of the mission parameters. Define the validation target and assess speed and success of RECUV reaction to a change in the mission plan.			
10	Assess the ability of RECUV to perform compliant tasks. Validation criteria is the subjective assessment of the quality RECUV compliant tasks performance.			

ANNEX D. CADDY Second Validation Trial Questionnaire: Underwater archaeology mission

The purpose of this questionnaire is to assess compliance of CADDY system with the validation plan. Please indicate the system compliance with each of the statements, by placing an **x** in the appropriate box. Fill out the comment tab when necessary.

Index			yes	no	comment
1	Is diver supported by the CADDY system able to efficiently and successfully guide the diver to the predefined position? Define acceptance accuracy and assess the performance against it.				
2	Is diver supported by the CADDY system able to safely recover the diver, upon mission completion?				
3	Is diver safety area preserved throughout the mission according to safety recommendations elaborated in the deliverable D6.1?				
4	Does system perform successfully dive buddy *"slave"* tasks? Assess speed and success of RECUV reaction and the mission performance.	Take a photo Illuminate the area Collect data for video mosaic			
	Assess precision and compliance of RECUV operations during the task.	Carrying a payload with tools and equipment			
5	Is communication link between the surface control centre and the underwater agents available when needed and provides reasonable flow of information using all possible topologies?				
6	Assess the speed and success of the divers behaviour interpretation, focusing on distinguishing normal diving behaviour from a divers' behaviour in stressful/anxiety situations. Define the validation target and assess the				

	rate of correctly interpreted behaviours and speed of interpretation against the target.			
7	Assess the speed and success of the symbolic signs and gestures interpretation and confirmation. Define the validation target and assess the rate of correctly interpreted and confirmed signs and gestures as well as speed of interpretation against the target.			

ANNEX E. CADDY Ergonomics Evaluation - Human Machine Interface Evaluation

The purpose of this questionnaire is to assess the usability of CADDY system and interface. Please indicate the extent to which you agree or disagree with each of the statements, by placing an **x** in the scale provided in each case.

Index		disagree				agree	
	User-friendliness	1	2	3	4	5	Comment
	Comfort and safety						
	I do not feel any discomfort when diving with buddy caused by installed acoustic equipment.						
	I could unmistakably recognize buddy kill switch's.						
	There is no ambiguity of how to activate kill switch.						
	It is easy to access and activate the kill switch?						
	I found the work with CADDY vehicles very comfortable.						
	Functionality						
2	CADDY helped me doing my work and fulfilling my task.						
3	I would like to use this system frequently.						
4	It was easy to handle the tablet and the program.						

5	The menu of the program was well arranged.						
6	The reaction time of the program was satisfying.						
7	I understood immediately what is meant by the messages displayed by the program						
8	CADDY did not disturb me physically						
9	CADDY kept a comfortable distance to me.						
10	CADDYs attention belonged to me.						
11	CADDY reacted to my digital instructions correctly.						
12	CADDY reacted to my gestures correctly.						
13	Have you been in a situation in which your emotional state changed (e.g. panic, fear)? If yes:						
13a	CADDY reacted to this change.						
13b	CADDY improved my situation by reacting to this change.						
14	CADDYs reaction to my instructions was rapid.						
15	I understood the instructions/ suggestions CADDY gave me.						
16	The communication between CADDY and me was satisfying						
	Assessment of subjective mental workload	High/ Poor				Low/ Good	
	Rate the Mental Demand from 1 (low) to 5 (high).						
	How much mental and perceptual activity						

	was required (e.g., thinking, deciding, calculating, remembering, looking, searching)? Was the task easy or demanding, simple or complex, exacting or forgiving?						
	Rate the Physical Demand from 1 (low) to 5 (high). How much physical activity was required? Was the task easy or demanding, slow or brisk, restful or laborious?						
	Rate the Performance from 1 (good) to 5 (poor). How successful do you think you, aided by the CADDY system, were in accomplishing the tasks?						
	Rate the Frustration Level from 1 (low) to 5 (high). How insecure, discouraged, irritated, stressed, and annoyed or secure, content, relaxed did you feel during the task?						